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TNO report

MT-RAP-2008-00100/mso

Summary of coating surveys on the four air command frigates (Zeven Provinciën class)

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Onderzoek naar de conditie van de coatingsystemen op vier luchtcommandofregatten (Zeven Provinciën klasse)

Onderhoudskosten van marinematerieel kunnen worden gereduceerd door een algehele verbetering in het afwerkingniveau en een intensievere controle daarop en het inzetten van goed presterende coatingsystemen.

Probleemstelling

Binnen de Koninklijke Marine is in 2005 discussie ontstaan over het gebrek aan kwaliteit van de toegepaste conserveringssystemen op de vier luchtcommandofregatten (Zeven Provinciën klasse). Aanleiding was in eerste instantie een aantasting van staal in de sewage verzameltank op LCF 1. Nadien zijn ook andere onderdelen van de fregatten in de discussie betrokken, alsmede andere schepen. In opdracht van en in samenwerking met de Defensie Materieel Organisatie is door TNO Industrie en Techniek/Quality Services B.V. een inspectiesystematiek opgesteld voor de inventarisatie van de conditie van coating systemen. Dit om de juistheid van de discussie over de vermeende mindere coatingkwaliteit te kunnen verifiëren. Van iedere LCF diende een selectie van tanks en scheepsvlakken te worden geïnspecteerd, alsmede het onderwaterschip, de topsides/opbouw en de dekken.

Beschrijving van de werkzaamheden

De geselecteerde delen van de luchtcommandofregatten zijn in een periode van 1½ jaar nauwgezet geïnspecteerd, teneinde de typen defecten vast te stellen en de omvang daarvan te kwantificeren. Resultaten zijn in protocollen verwerkt en uitgebreid fotografisch vastgelegd. Uiteindelijk is ook de conditie van de coatingsystemen op de luchtcommandofregatten onderling vergeleken.

Resultaten en conclusies

De conditie van de coatingsystemen blijkt om uiteenlopende redenen minder te zijn dan verwacht zou mogen worden gezien de relatief korte gebruiksperiode.

Een aantal van de systemen blijkt niet geschikt voor de toepassing (sewage tanks, grijswatertank 2, onderwaterschip LCF 3 en 4, F dek voor). De kwaliteit van laswerk in tanks laat te wensen over.

De kwaliteit van de applicatie van coating systemen in tanks varieert van slecht (drinkwater- en ballasttanks) tot redelijk en bevestigt dat de controle daarop tekort heeft geschoten. Scheepsvlakken in pompkamers 2 en 3 blijken door putcorrosie te worden aangetast. Verschillende materialen die aan dek worden toegepast corroderen. Compleet toegeleverde systemen voor buitentoepassing vertonen corrosie langs kritische plaatsen.
Onderhoudswerkzaamheden buiten kunnen of worden niet of nauwelijks uitgevoerd. Het vereiste kwaliteitsniveau voor herstelwerkzaamheden wordt aan boord niet bereikt. Dit in combinatie met het verweringsgedrag van de coatingsystemen en de roestsporen vanaf gecorrodeerde randen en beschadigingen en vanuit drains hebben consequenties voor het cosmetisch uiterlijk.

Toepasbaarheid

De resultaten van het onderzoek kunnen door de DMO / Koninklijke Marine worden gebruikt om coatingspecificaties te verbeteren en om het kwaliteitsniveau van de conservering, impliciet voorbehandeling en applicatie, voor toekomstige nieuwbouwprojecten te verhogen, zodat onderhoudskosten kunnen worden verminderd. Tevens kunnen de resultaten een aanzet geven tot het invoeren van of verbeteren van garantiebepalingen.

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Frequentie van overleg Het projectteam heeft vijf maal vergaderd over de invulling, de voortgang en rapportage van het onderzoek. Gedurende de gezamenlijke inspecties is frequent overleg gevoerd.	Projectteam Ing. H. Bakuwel (DMO / DWS / RZS / PLTFT) Ing. C. van Sevenhoven (DMO / DWS / RZS / PLTFT) Ing. R. van der Kaaden (TNO Quality Services B.V.) Ir. G.M. Ferrari (TNO Industrie & Techniek)

Contents

1 Introduction

By the order of DMO, TNO has executed an inventory into the condition of the coating and deck covering systems applied on four air command frigates of the Zeven Provinciën class (Dutch: Luchtcommandofregatten or LCF).

The activities have been initiated following the observations in the sewage tank of LCF 1 (Hr.Ms. "Zeven Provinciën"), which showed significant steel wastage necessitating steel renewal. Analyses into the cause of the corrosion also included the evaluation of the selected coating system. After the inspection by the Royal Netherlands Navy, indications within the navy organisation have been received concerning the apparent poor condition of coating systems already occurring after a short service period. Additionally, previous coating breakdown on Hr.Ms. "Rotterdam" played a role of importance. Experiences of the Royal Netherlands Navy have been documented in DMO-MARTECH report D5050-0473, dated October 24, 2005, entitled "Quality tank coatings LCF-class". For detailed information, reference is made to the contents of this document.

The Royal Dutch Navy has expressed the necessity to evaluate the obvious preservation problems and to assess the current condition of the various coating systems by an independent company. For this purpose, TNO Science and Industry (TNO) has been invited.

The Royal Netherlands Navy and TNO have developed an inspection method in the period September 2005 – February 2006. A document has been drafted, entitled "General description inspection protocols LCF class", which served as a basis for the inspection and evaluation of inspection results.

The inventory involves an accurate inspection of a selection of vessel parts divided into five categories tanks, bilges, underwater hull, topside and superstructure and decks. A distinction has been made of the types of failures and their causes; the affected surface area needs to be determined as accurately as possible.

In the internal memorandum MAT 05422 (version 2) of the Royal Netherlands Navy, dated October 17, 2005, the field of research has been described in paragraph 4. The following aspects need to be assessed on board of the frigates by means of inspections:

1. The current status and service life of the coating systems.
2. The nature and extent of possible failures.
3. The possible cause of failures, provided that this can be assessed easily.
4. The expected remaining service life of the coating systems.
5. The quality reports for each coating system (protocols, survey reports, claims, sea trial reports).
6. The conditions coating systems have been exposed to during the service period.
7. Possible executed repairs and/or scheduled maintenance
8. Particularities regarding specific environmental conditions around the coating systems.

An inspection protocol has been drafted by DMO per category to facilitate and standardise the inspection, including and inspection form to be filled in. Additional, a selection of photos is added describing the current condition.

Table 1: Overview dates

Frigate		Inauguration date	In service since	Inspection period
Name	Code			
Hr.Ms. "Zeven Provinciën"	LCF 1	08.04.00	26.04.02	06.09.06-04.10.07
Hr.Ms. "Tromp"	LCF 2	07.04.01	14.03.03	28.06.06-11.08.06
Hr.Ms. "De Ruyter"	LCF 3	13.04.02	22.04.04	05.09.06-08.12.06
Hr.Ms. "Evertsen"	LCF 4	19.04.03	10.06.05	20.02.06-05.04.06

As can be seen from table 1, various areas of all four frigates have been inspected in the period 20.02.2006 – 04.10.2007. Inspection have been executed either in Vlissingen or Den Helder, The Netherlands. Results of these inspections have been drafted into the following extensive reports for each frigate:

- TQS-RAP-07-855/gge of March 30, 2007 for Hr.Ms. "Evertsen" (LCF 4)
- TQS-RAP-07-856/gge of March 30, 2007 for Hr.Ms. "Tromp" (LCF 2)
- TQS-RAP-07-857/gge of March 30, 2007 for Hr.Ms. "De Ruyter" (LCF 3)
- TQS-RAP-08-3316/gge of January 10, 2008 for Hr.Ms. "Zeven Provinciën" (LCF 1)

Each report consists of a description of results and all protocols made up. A separate DVD with photos and PDF files of the reports and protocols has been made for each LCF.

Additionally, an intermediate report TC-RAP-06-28190/gge, dated November 28, 2006, has been produced entitled "Summary of results of inspections of ballast tanks, potable water tanks, sewage tanks and fuel tanks on four air command frigates". The report described the results of the inspections in four types of tanks, causes of problems and possibilities for repair. At the stage of drafting this report, inspections had not been completed yet.

For detailed information reference is made to the contents of the reports.

This report describes the main results of the inspections on all four LCF's with the aim of obtaining an impression of the general condition of coating systems applied on various areas as well as to address possible structural problems. Following the evaluation of the condition, preservation recommendations have been drafted for future newbuildings.

2 Results

The damaged surfaces have been quantified using two factors:

- The number of defects and the distribution,
- The percentages of defects related to the total surface area.

For the temporarily corrosion protection of steel during building of the four frigates, the shopprimer Sigmaweld MC has been used which has been applied in a dry film thickness of approx. 22 μm onto Sa 2½ blasted steel.

In this report, results have been summarized in tables. In order to further illustrate findings, graphs have been made as well. In several graphs damages have been expressed as a percentage of the coated surface area. This surface area has been derived from tank volume data available on the LCF's, which have been transformed into surfaces using estimated surface/volume factors (usually in the range of 3.5-4 m^2/m^3).

Interpretation of graphs is to be executed with care and in combination with values in the tables. This, because tank inspections on LCF's have not been carried out in the same tank on each LCF and some tanks have not been inspected completely.

In order to illustrate some of the main findings during the inspections, a selection of photos has been enclosed in appendix 1.

2.1 Tanks

In this chapter, the results of the inspections in various types of tanks have been evaluated. Mostly, the number of spots and percentages affected by corrosion have been mentioned. In some tanks, blistering has occurred. This has been evaluated separately.

For the preservation of tanks three different coating specifications have been used. The systems are shown in table 2:

Table 2: Overview tank coating systems

Tank	Preservation
Potable water tanks	Complete blasting to surface cleanliness Sa 2½ 1 F/C Sigmaguard CSF 85, 300 μm
Water ballast tanks Sewage tanks Heli fuel storage tank Heli fuel consumption tank Grey water tanks Bilge water collection tank	Welds and burnt spots blasting to Sa 2½, sweeping of remaining surface 1 F/C Sigma EP Universal Primer, 50 μm 1 F/C Sigmaguard EHB, 125 μm 1 F/C Sigmaguard EHB, 125 μm
Fuel storage tanks Fuel consumption tanks Dirty oil tank	Welds and burnt spots grinding (St 3) 1 F/C Sigma EP Universal Primer, 50 μm

In addition to full coats, stripe coats have been applied prior to or after application of a full coat to ascertain proper coverage of more critical areas.

2.1.1 *Potable water tanks*

The failures occurring in the potable water tanks can be summarised as follows:

Table 3: Overview coating failures potable water tanks

LCF	Tank	Volume [m³]	Surface area [m²]	Corrosion (1) Number	Corrosion (1) Surface [cm²]	Blisters Surface [cm²]	Blisters Location (3)
LCF 1	PWT 1	18,6	65	135	620,75	179200	S/C - F/C
	PWT 2	18,6	65	64	42,31	193000	S/C - F/C
	PWT 3	22	77	41	10,21	133500	S/C - F/C
	PWT 4	22	77	56	5,5	163000	S/C - F/C
LCF 2	PWT 1	18,6	65	42	32,11	18250	S/C - F/C
	PWT 2 (2)	18,6	65	several		> 0	
	PWT 3	22	77	5	0,05	82000	S/C - F/C
	PWT 4	22	77	13	3,1	42000	S/C - F/C
LCF 3	PWT 1	18,6	65	60	65	133500	F/C - S/C
	PWT 2	18,6	65	117	117	127500	F/C - S/C
	PWT 3	22	77	23	1,15	24960	F/C - S/C
	PWT 4	22	77	13	11,02	40000	F/C - S/C
LCF 4	PWT 1	18,6	65	48	15,27	0	
	PWT 2	18,6	65	35	126,45	0	
	PWT 3	22	77	16	0,25	0	
	PWT 4	22	77	26	3,97	0	

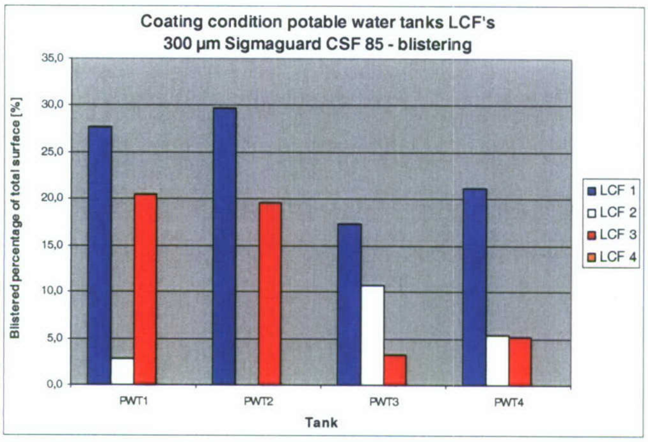
(1) Corrosion through pinholes, poorly covered spots or cracks
(2) The defects in this tank have not been quantified
(3) S/C is stripe coat, F/C is full coat

Typical phenomena in potable water tanks are:

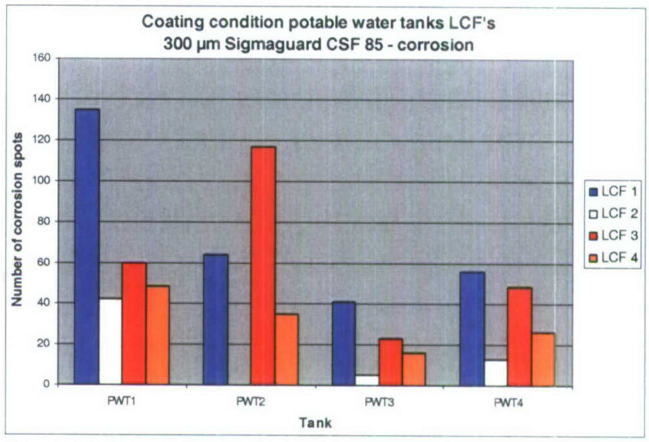
- Blistering in between coating layers has occurred on LCF 1, 2 and 3 and not on the newest frigate LCF 4. Blistering occurs between a stripe coat and a full coat (LCF 1 and 2) or between a full coat and a stripe coat (LCF 3). This concerns areas along welds and welding corners (photo 1 in appendix 1).
- Generally, the adhesion in blistered areas is poor. The area affected by blistering varies from 2,5 m² to 20 m² per tank. Two spots showing spontaneous detachment in blistered areas resulting in corrosion of the underlying steel have been disclosed in tank 1 of LCF 1. Such a propagation of the damages is highly undesired. In all other tanks, blisters are still intact.
- The observed blisters should not occur in a coating system which has been applied according the regulations and performs satisfactorily.
- Blistering in potable water tanks of LCF 1 was already observed prior to delivery of the vessel (information DMO).
- Typically, the surface structure of the coating is wrinkled (surface as well as in between blisters).
- Taking into account the limited surface of the tanks relatively many (small) corrosion spots are present along welding seams and edges (photo 2).
- Undercreep of corrosion between steel and coating and wastage of the steel occurs after longer service periods of the LCF's (effects chlorination).
- Typical application shortcomings (sub standard thickness, saggings, excessive thicknesses) have occurred in limited amounts.

- It has been observed in several tanks that corrosion has set in and originated from pinholes in the coating. Solvent free coating systems are more susceptible to pinhole formation compared to solvent containing systems. Pinholes within the coating system have not been repaired adequately during the preservation of the tanks.

Results have been transformed into the following graphs showing the percentage of the surface affected by blistering (left) and the number of corrosion spots (right):



Graph 1: Blistering in potable water tanks



Graph 2: Corrosion in potable water tanks

2.1.2 *Water ballast tanks*

The failures occurring in the ballast tanks can be summarised as follows:

Table 4: Overview coating failures water ballast tanks

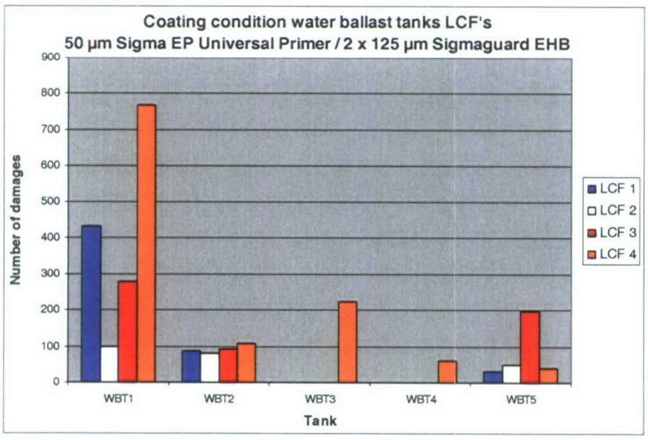
LCF	Tank	Volume [m³]	Surface area [m²]	Corrosion + blistering		Cracks	
				Number	Surface [cm²]	Number	Surface [cm²]
LCF 1	Ballast tank 1	149,8	524	433	6190	0	
	Ballast tank 2	30,9	124	86	1470,61	67	1890
	Ballast tank 3	48,6	194	not in scope			
	Ballast tank 4	70,2	246	repairs in progress, cathodic blistering			
	Ballast tank 5	70,2	246	31	3,79	6	6
LCF 2	Ballast tank 1	149,8	524	> 100	> 0	> 100	1-2 %
	Ballast tank 2	30,9	124	80	229	6	23
	Ballast tank 3	48,6	194	not in scope			
	Ballast tank 4	70,2	246	not in scope			
	Ballast tank 5	70,2	246	several	> 0	0	
LCF 3	Ballast tank 1	149,8	524	280	66	0	
	Ballast tank 2	30,9	124	93	44513,6 (1)	0	
	Ballast tank 3	48,6	194	not in scope			
	Ballast tank 4	70,2	246	not in scope			
	Ballast tank 5	70,2	246	198	7382,4	0	
LCF 4	Ballast tank 1	149,8	524	769	61	10	140
	Ballast tank 2	30,9	124	108	253	0	
	Ballast tank 3	48,6	194	225	1653,25	9	19
	Ballast tank 4	70,2	246	62	1927	0	
	Ballast tank 5	70,2	246	41	162	0	

(1) consists of 44200 cm² blistering underdecks

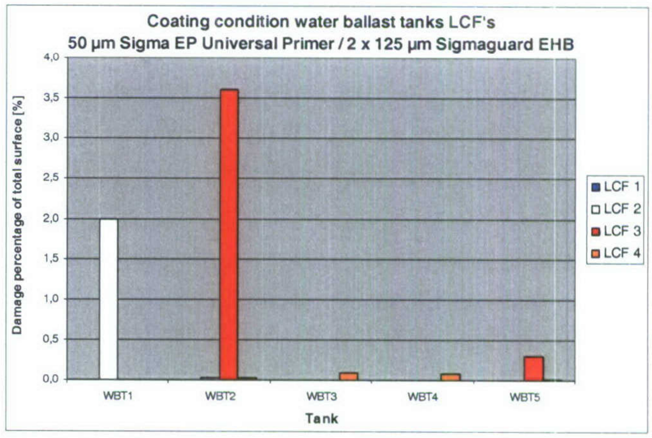
Remarkable phenomena in the water ballast tanks are:

- Cracking in the coating along welding seams occurs in ballast tank 2 of LCF 1 (photo 3), ballast tanks 1 and 2 of LCF 2 (photo 4) and in a limited amount in ballast tanks 1 and 3 of LCF 4. The coating thickness is normal and not excessively high. Water ballast tanks of LCF 2 have been used to a higher extent compared to LCF 1 and 3.
- Considering the limited surface of the tanks, very many to extreme amounts of (small) corrosion spots are present on surface and on welding seams (photo 5).
- Other application shortcomings (sub standard thickness, saggings, excessive thicknesses) occur to a lesser extent. Pinholes have been formed in the coating system at places, especially in areas which can be reached more difficult.
- The welds show small irregularities which should have been noted and rejected during the steel inspections; generally the irregularities are poorly covered.
- Cathodic blistering has developed in the coating around damages, pinholes and on poorly covered spots. These alkaline blisters between steel and coating are formed due to the cathodic protection in the tanks. This phenomenon mainly occurs in ballast tanks 1, 2 and 4 of LCF 1 and ballast tank 5 of LCF 3 (photo 6).
- Anodes have been mounted on a height of approx. 1 m from the deepest point in ballast tanks 1. This implies that the cathodic protection does not work when water levels are relatively low.

Results have been transformed into the following graphs showing the number of damages per tank per LCF (left) and the surface percentages affected by defects (right):



Graph 3: Number of defects in water ballast tanks



Graph 4: Affected surface percentages in water ballast tanks

2.1.3 *Sewage tanks*

Summarising, the amounts of defects in the sewage collection and storage tanks are as follows:

Table 5: Overview coating failures sewage tanks

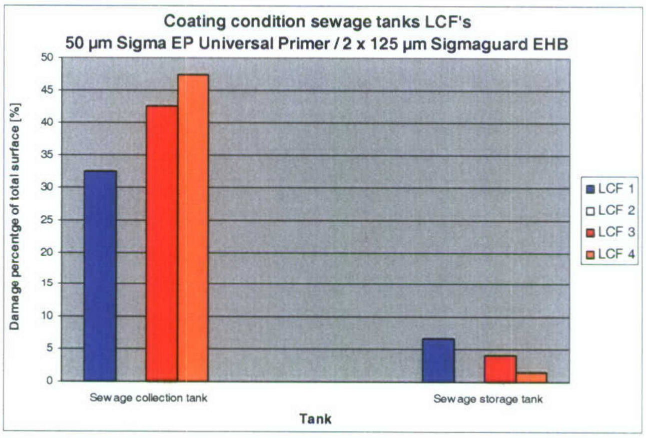
LCF	Sewage collection tank				Sewage storage tank			
	Volume [m³]	Surface area [m²]	Corrosion [cm²]	Blisters [cm²]	Volume [m³]	Surface area [m²]	Corrosion [cm²]	Blisters [cm²]
LCF 1	5,7	20	0,1	65000	28,4	99,4	0,2	66450
LCF 2 (1)	5,7	20	some	many	28,4	99,4	some	limited
LCF 3	5,7	20	0	85100	28,4	99,4	582	40985
LCF 4	5,7	20	0,7	95000	28,4	99,4	1,85	15000

(1) The defects in these tanks have not been quantified.

It is remarked that on LCF 1, the complete coating system has been renewed in the sewage collection tank before and that a part of the bottom plating was replaced due to severe steel wastage. The most apparent effects in the sewage collection and storage tanks were the following:

- Especially in the collection tanks, significant areas have been affected by blistering (photo 7). On LCF 4, the first frigate to be inspected, blistering had occurred in various places within the coating system. Subsequent inspections on LCF 1, 2 and 3 proved that blistering is a structural problem.
- Blistering has also occurred in the sewage storage tanks though to a far lesser extent.
- Both in the sewage collection and storage tank, corrosion is limited to a few spots (photo 8). As far as could be assessed, deep steel wastage has not occurred.
- The extremely poor condition of Cunifer piping in the tanks of LCF 1 (perforations) was striking (photo 9). GRP piping has been installed instead on all LCF's.

Results have been transformed into the following graph showing damage percentages:



Graph 5: Affected surface percentages in sewage tanks

2.1.4 *Fuel tanks*

2.1.4.1 *Fuel storage and consumption tanks*

Fuel storage and consumption tanks have to be coated with 50 µm Sigma EP Universal Primer. The amounts of defects in these tanks have been summarised as follows in table 6:

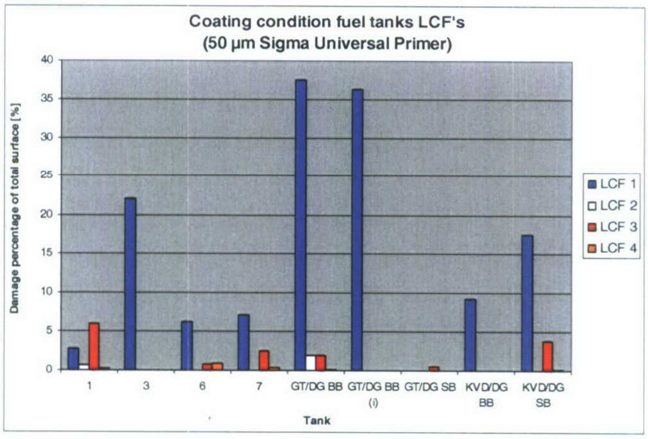
Table 6: Overview coating failures fuel storage and consumption tanks

Tank	Volume [m³]	Surface area [m²]	Total defect surface [cm²]			
			LCF 1	LCF 2	LCF 3	LCF 4
Fuel storage tank 1	122	488	136600	< 35000	286650 (1)	5270 (2)
Fuel storage tank 3	50,5	177	389750 (1)	x	x	x
Fuel storage tank 6	46,39	162	100000	several m² (3)	12720	15820
Fuel storage tank 7	46,39	162	114800	several m² (3)	39600	5753
Fuel consumption tank GT/DG BB	50,6	177	663750	35200	35650	1560
Fuel inlet tank GT/DG BB	2,5	9	32750	x	x	0
Fuel consumption tank GT/DG SB	50,6	177	x	x	9100	x
Fuel consumption tank KVD/DG BB	36,3	127	116100	x	x	x
Fuel consumption tank KVD/DG SB	36,3	127	222250 (4)	0	47760	1454

x = not inspected
(1) 75-80 % of surface inspected
(2) 35 % of surface inspected
(3) not quantified accurately
(4) not entered (not cleaned), inspected from manhole opening

- All damages observed have been added up per tank completely. This implies that the values in the table do not discriminate between blistering and corrosion.
- Only on LCF 1, several of the tanks have not been coated completely, as was the case on a few frame fields on LCF 2. Due to this, uncoated areas have developed corrosion, which has resulted in relatively large areas with damages (photo 10).
- In fully coated tanks, the amounts of corrosion are generally low (photo 11). Pitting corrosion has been observed (by DMO) only in a bottom panel in fuel consumption tank 2 on LCF 1.
- In virtually all inspected tanks blistering has occurred between (shopprimed) steel and coating. In most cases blistering is present on the hull part and some horizontal stiffeners and concentrated in lower parts of the tanks. The blister intensity is high, the diameter usually varies between 0.5 – 2 mm (photo 12). The steel under blisters is usually black or brown.
- In tanks on all LCF's, typical damage patterns have been observed where blistering was more intense in areas with a low coating thickness (< 50-70 μm) and less intense in surrounding areas with a higher coating thickness (> 80-100 μm).
- In some tanks on LCF 3, several layers of coating have been applied on places and blistering and detachment has occurred between individual coating layers.

Results have been transformed into the following graph showing damage percentages:



Graph 6: Affected surface percentages in fuel tanks

The graph illustrates that fuel tanks on LCF 1 have been affected to the highest level. This is due to the fact that areas in tanks on this LCF have not been coated completely.

2.1.4.2 *Heli fuel storage and consumption tanks*

The heli fuel tanks have been coated with a three layer epoxy system. The observed damages have been summarized in table 7.

Table 7: Overview coating failures in heli fuel tanks

LCF	Heli fuel storage tank				Heli fuel consumption tank			
	Volume [m³]	Surface area [m²]	Number	Surface [cm²]	Volume [m³]	Surface area [m²]	Number	Surface [cm²]
LCF 1	57,1	228,4	10	218	8,5	34	x	x
LCF 2	57,1	228,4	several	not quantified	8,5	34	x	x
LCF 3	57,1	228,4	18	1556	8,5	34	3	101
LCF 4	57,1	228,4	21	756	8,5	34	x	x

x = not inspected

- Corrosion is more or less absent, most likely due to the fact that the heli fuel is virtually free of water. Weak spots have been observed within the coating system though.
- The amount of damages is limited. The highest damage percentage is less than 0.07 % of the tank surface (heli fuel storage tank on LCF 3).
- In most of the tanks the final quality of the sprayed surface could be improved
- The coating contains large amounts of pinholes and poorly covered welds (spraying shadows, photo 13) and occasional cracks due to excessive thicknesses.
- Occasionally, burnt spots are present.

2.1.5 *Grey water tanks*

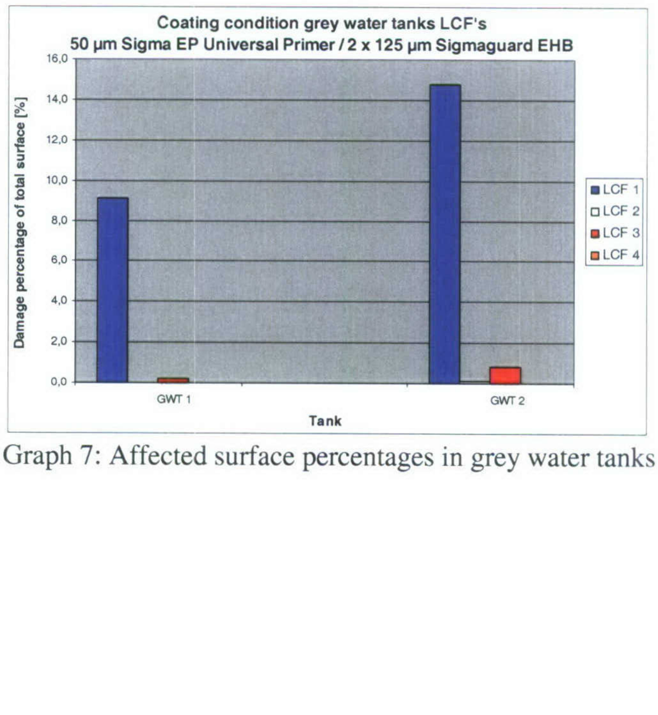
The coating condition in the two grey water tanks shows typical differences as is expressed in table 8.

Table 8: Overview coating failures in grey water tanks

LCF	GWT 1				GWT 2			
	Volume [m³]	Surface area [m²]	Number	Surface [cm²]	Volume [m³]	Surface area [m²]	Number	Surface [cm²]
LCF 1	12,4	43,4	> 38	40000	5,8	23,2	many	65000
LCF 2	12,4	43,4	some		5,8	23,2	several	500
LCF 3	12,4	43,4	21	840	5,8	23,2	20	3515
LCF 4	12,4	43,4	11	30	5,8	23,2	23	62

- Generally, the coating condition in tank 1 is significantly better compared to the condition in tank 2. This must be due to conditions inside the tanks. Grey water tank 2 is used for galley water which can be aggressive as a result of fatty acids.
- Grey water tank 2 on LCF 1 is by far in the poorest condition (photo 14). Signs of breakdown though have been observed on LCF 2 and 3 as well.
- In time the coating system in grey water tank 2 is damaged, weakened and disappears.
- Besides the general breakdown, minor damages have been a result of pores in welds, cracks in a thick coating layer and mechanical damages.
- Typically, repaired spots in grey water tank 2 on LCF 3 have developed blisters.

Results have been transformed into the following graph showing the total damage percentages:



Graph 7: Affected surface percentages in grey water tanks

2.1.6 *Bilge water collection tanks*

The defects in the bilge water collection tanks are limited as can be seen from the values in table 9:

Table 9: Overview coating failures in bilge water collection tanks

LCF	Number of spots in compartment from SB		
	- 1 -	- 2 -	- 3 -
LCF 1	0	6 (3 cm²)	0
LCF 2	few spots on welds		
LCF 3	0	1 pit 3 mm	0
LCF 4	9 (0,57 cm²)	11 (100,1 cm²)	6 (0,08 cm²)

- In general, the coating system in the tanks is in a good condition.
- The amounts of corrosion are almost negligible. In one case (LCF 3) a pitted spot was disclosed on the tank bottom.
- The largest damages have occurred in the bilge water collection tank on LCF 4 due to cracking in a too thick applied coating system (100 cm²). On LCF 4, corrosion spots have also occurred on welds (photo 15).
- Defects on LCF 1 are most likely due to mechanical damages, which have occurred during cleaning of the tank.
- Occasionally, some pinhole formation has been observed in the coating surface in corners.

2.1.7 *Dirty oil tanks*

The damages in the dirty oil tanks are restricted to the spots which have been summarised in table 10.

Table 10: Overview coating failures in dirty oil tanks

LCF	Number of spots in compartment from PS		
	- 1 -	- 2 -	- 3 -
LCF 1	20-30 % of surface uncoated and corroded		
		1 pit 3 mm	1 pit 1 mm
LCF 2	0	0	0
LCF 3	0	6 (0,06 cm²)	0
LCF 4	10 (10 cm²)	2 (0,2 cm²) 3 pits 1-2 mm	3 (0,01 cm²)

- Generally, the coating system in the tanks is in a good condition (photo 16).
- The dirty oil tank on LCF 1 is the only tank of four where the surface has not been coated completely. Uncoated areas cover 20-30 % of the surface. As a result, especially the lower bare steel surfaces have developed corrosion here. Furthermore, some local blistering has been observed within the primer coating.
- Some minor pitting corrosion could be observed in two compartments on LCF 1 and one compartment on LCF 4.
- Some corrosion is occurring along welds.

2.2 Bilges

The bilges have been treated as follows:

- Welds and burnt spots mechanical derusting
- 1 F/C Sigma EP Universal Primer, 50 μm
- 1 F/C Sigmaguard EHB, 125 μm
- 1 F/C Sigmaguard EHB, 125 μm

Obtaining a full impression of the bilges was virtually impossible due to the poor accessibility of several of the areas, as well as due to the fact that frequently layers of (salt) water and oil were present in deeper parts making an inspection impossible (photo 17).

The defects in the bilges have been divided in two separate tables. In table 11, the number of pits in the inspected bilges has been summarised. In table 12, the amounts of corrosion due to various causes have been summarised.

Table 11: Overview of number of pits in bilges

LCF	Number of pits in bilges:			
	Pump room 2	Forward engineroom	Pump room 3	Dieselgeneratorroom
LCF 1	48	0	9	0
LCF 2	few	0	not inspected	0
LCF 3	8	1	3	0
LCF 4	14	0	0	0

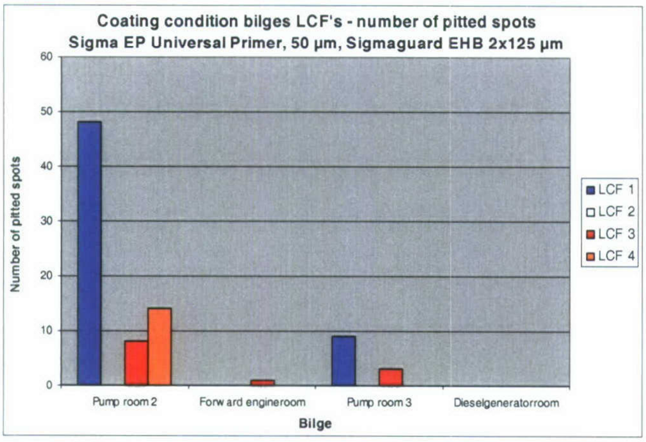
Table 12: Overview of amounts of corrosion in bilges

LCF	Corroded surfaces in bilges [cm²]:			
	Pump room 2	Forward engineroom	Pump room 3	Dieselgeneratorroom
LCF 1	115 (1)	235	160	80
LCF 2	< 10	5	not inspected	0
LCF 3	500	250	250	190
LCF 4	5 (2)	5	200	5

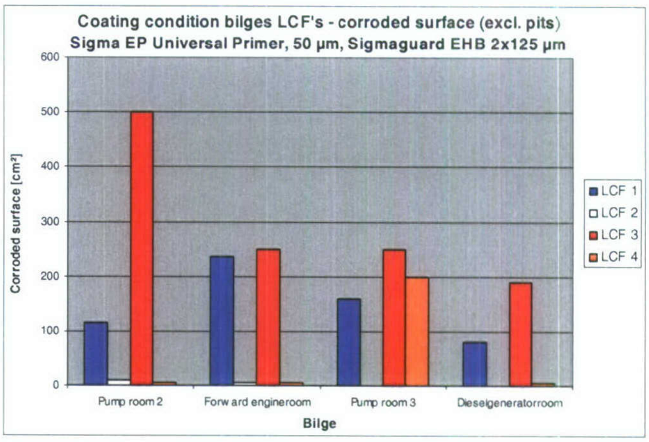
(1) and 50 cm² blister and detachment between coating layers
(2) and 600 cm² blisters between coating layers

- On all LCF's, pitting corrosion has been observed in bilges, especially in pump rooms 2 and 3 (photo 18). The depths of the pits varied from approx. 1 mm up to 6-7 mm.
- A black substance was present in the pits.
- Additional investigations have been carried out into the cause of pitting in pump room 2 on LCF 1. Sulphur reducing bacteria have been identified, as well as fungi. Sulphur reducing bacteria can result in pitting corrosion. Access to the steel was possible due to the mechanical damages.
- As can be expected in bilges, the coating system frequently shows corrosion as a result of mechanical damages. Additionally metallic particles are present on the coating surfaces, which develop corrosion.
- Cracks due to high coating thicknesses sometimes reaching the steel resulted in penetrating corrosion.

Observed defects shown in tables 11 and 12 have been transformed into graphs to further illustrate the differences between the LCF's.



Graph 8: Number of pitted spots in bilges



Graph 9: Corroded surfaces in bilges

2.3 Underwater hulls

Underwater hulls have been treated with different coating systems, which is illustrated in table 13 showing the individual coating layers. On LCF 1 and 2, an organotin based antifouling (Sigmaplane) has been applied; on LCF 3 and 4 the copper containing antifouling (AlphaGen) was used.

Table 13: Coating specifications underwater hulls LCF's

Systems	LCF 1	LCF 2	LCF 3	LCF 4
Blasting to surface cleanliness Sa 2½	x	x	x	x
1 F/C Sigma EP Universal Primer, 50 µm	x	x	x	x
1 F/C Sigma EP Multiguard, 150 µm	x	x	x	x
1 F/C Sigma EP Multiguard, 150 µm	x	x	x	x
1 F/C Sigma Tiecoat, 75 µm	x	x	x	x
1 F/C Sigmaplane HB, 100 µm, before launching	x	x	x	
1 F/C Sigmaplane NC, 125 µm	x	x		
1 F/C Sigmaplane HB, 125 µm	x	x		
1 F/C Sigma AlphaGen 20, 100 µm, before launching				x
1 F/C Sigma AlphaGen 20, 150 µm			x	x
1 F/C Sigma AlphaGen 20, 150 µm			x	x

Detachments of antifouling appeared to be a major issue on the hulls. Percentages of detachments have been summarised in table 14.

Table 14: Overview of detachments on underwater hulls

LCF	Antifouling detachment [%] of surface	
	PS	SB
LCF 1	0	0
LCF 2	0	0
LCF 3	10-15	30-35
LCF 4	30	17

- The underwater hull coating system of LCF 1 and 2 is in a significantly better condition compared to LCF 3 and 4.
- The values in the table show that detachments have occurred on the hulls coated with AlphaGen antifouling only. Significant surfaces have detached both between antifouling layers and, to a lesser extent, between tiecoat and antifouling (photos 19 and 20).
- Due to the detachments, the condition of the hulls of LCF 3 and 4 is poor. The fact that similar problems have occurred on two hulls points in the direction of a product related cause. Insufficient cleaning prior to application of the final coating layer, which was submerged about one year, has been considered as a possible cause before, the likelihood though can be doubted. Application conditions are unknown but could have had an impact as well.
- Both on LCF 3 and 4 irregular surfaces and repaired areas have been observed indicating that detachment problems have occurred in an earlier stage, most likely during the building process.
- Fouling rates on organotin and copper antifouling surfaces are comparably low.
- Some minor micro-cracking could be observed within the organotin surfaces.
- The antifouling which has been applied on the boottop is intact.
- From a corrosion point of view all underwater hulls are in an excellent condition. Only a few minor corrosion spots could be observed on each hull.
- The underwater coating system (anti-corrosive and antifouling) has not show any detrimental effect in relation to the applied cathodic protection system.
- A test area on PS of LCF 2 has been treated with Foul Release Coating Sigmaglide. Barnacles and algae had attached to the surface, most of which could be removed during cleaning. Remaining barnacles were easy to remove manually.

2.4 Topsides and SB/PS areas

The topsides and the PS/SB exterior surfaces of the superstructure have been inspected together. These areas have been coated as follows:

- 1 F/C Sigma EP Universal Primer, 100 μm on topsides, 75 μm on superstructure
- 1 F/C Sigma CM Coating, 150 μm
- 1 F/C Sigmadur Gloss, 50 μm
- 1 F/C Sigmadur Gloss, 50 μm

The observed damages have been summarized in table 15.

Table 15: Defects on PS/SB exterior surfaces

LCF	Corrosion due to damages		Detachments
	Number	Surface [m²]	Surface [m²]
LCF 1	2050	0,971	19
LCF 2	>> 100	not quantified	0
LCF 3	1235	0,851	0
LCF 4	170	0,818	0

- As can be expected, the number of corrosion spots increases when service periods are longer.
- Mechanical damages concentrate around the vertical sides of the crane deck, edges of the heli deck (photo 21), edges of various doors and of the F deck.
- The mechanical damages have resulted in corrosion. It was estimated that the total corroded surface due to mechanical damages did not exceed 1 m² on each LCF.

- Water outlets have been positioned on a relatively high level in the sides of the LCF's resulting in brown traces running down.
- Some maintenance has been carried out during the service periods. This has resulted in differences in gloss and colour.
  Repairs have not always been carried out successfully, as was observed during cleaning of LCF 3, where the repair coat had detached already and could be washed off easily (photo 22).
- Only on LCF1 detachment within the coating system (topcoat from midcoat) was observed both on PS and SB just above the boottop (photo 23). Several areas had been repaired here prior to the inspection by TNO. This type of detachment was also observed on other areas of LCF 1 though only spot wise.

2.5 Superstructure

The painting specification for the superstructure is identical to the specification described in chapter 2.4.

- On LCF 1-3, repairs had already been carried out indicating that corrosion had set in at an earlier stage. Several repaired spots had developed corrosion again.
- The two colours of Sigmadur Topcoat which have been used on the LCF's show a reduced gloss and have a powdery surface on LCF's 1-3 (photo 24). Only on LCF 4, which has been in service for the shortest period of time, these effects could not be observed at the moment of the inspection by TNO.
- In general, the coating system functions as expected. Only on LCF 1 several areas could be discriminated where the topcoat had detached from the epoxy coating, as was the case on the topsides of this LCF. The following areas have been disclosed:

  - D-deck forward: PS under overhang
  - E-deck aft: SB edge
  - E-deck forward: Near weld overhang
  - F-deck forward: Under overhang PS
  - H-deck: Underdecks PS (largest area)

- Corrosion has developed due to mechanical damages and along edges of steel structures.
- Appliances which have been prefitted and mounted completely onto the LCF's show structural corrosion problems on all LCF's as well as other critical areas. This concerns:

  - Stainless steel bolts/head screws (photo 25)/frames mounted on aluminium and/or steel result in coating failures (due to galvanic coupling).
  - Sharp edges and substandard coating thicknesses on parts which have been mounted onto the decks (photo 26).
  - Application of steel rings which corrode.
  - Hinged joints.
  - Edges/surfaces of various appliances.

2.6 Decks

The decks have been preserved as follows:

- 1 F/C Sigma EP Universal Primer, 75 μm
- 1 F/C Sigma CM Coating, 150 μm
- Sigmadur Antislip

or:

- 1 F/C Bolidt primer PU/LP 2581, 40 μm
- 1 F/C Bolidt flooring PU/NF, 1500 μm
- Bolidt flooring quartz,
  0,7 – 1,2 mm for heli- and hangar deck and 0,3 – 0,7 mm for decks outside
- Bolidt covering PU/SH + anti graffity layer Dypol 2006

The following has been observed:

- Comparing the condition of the decks on all four LCF's, it appeared that decks on LCF 1 are by far in the worst condition. This goes especially for the F-deck forward (photo 27). Corroded spots though have been observed on other decks as well. Additionally, a dark grey topcoat detached partially (photo 28).
- On the F-deck, ammunition drops on the flooring resulting in mechanical damages on LCF 1 and 2 (photo 29). On LCF 3 rubber covering have been placed on top of the decks successfully preventing the impact. On LCF 4 damages had not yet occurred at the moment of the inspection.
- Corrosion sets in from edges of decks, which have been applied until welding seams/corners. From there, corrosion expands into surrounding surfaces (photo 24) and even spreads onto adjacent vertical surfaces.
- Lashing points have developed corrosion on all heli decks (photo 28).
- During all inspections, decks appeared to be relatively dirty (photo 30).
- Sometimes metal particles have started to corrode resulting in small brown stains.

3 Conclusions

The type and extent of coating defects on various parts on four LCF's have been assessed during numerous surveys within a period of more than 1½ year. Based on the results, the following main conclusions regarding the current condition of coating systems can be drafted:

- Water ballast tanks, potable water tanks, sewage tanks, grey water tanks, fuel storage tanks show (extremely) large amounts of damaged spots or large areas affected by damages within a relatively short service period.
- Pitting corrosion concentrates in bilges in pump room 2 and 3. Occasionally, a small pitted spot has been observed in a water ballast tank, a fuel tank and a dirty oil tank.
- The copper containing antifouling applied on LCF 3 and 4 performs poorly due to detachments.
- Exterior surfaces show corrosion due to the design, selection of materials, lack of maintenance. Decks on LCF 1 are in a significantly poorer condition compared to the other LCF's.

In the individual reports of the LCF's, the areas showing a condition which has been considered to be less than can be expected for a properly applied preservation in relation to the service life have been mentioned in the conclusions and are combined in table 16.

Table 16: Areas showing most prominent defects

Area	LCF 1	LCF 2	LCF 3	LCF 4
Potable water tanks	X	X	X	X
Water ballast tanks	X	X	X	X
Sewage collection tank	X	X	X	X
Grey water tank 2	X		X	
Pump room 2	X	X	X	X
Pump room 3	X		X	
Underwater hull			X	X
Decks/superstructure	X			
Critical points appliances in superstructure	X	X	X	

The performance of coating systems in general depends on the design of the system (steel work, pretreatment, coating system and application, surveying), the environmental conditions and maintenance carried out. Relevant parts of each of these aspects will be described in brief here after.

High performance coating systems which have been applied onto a properly pretreated surface in accordance with the instructions of the paint manufacturer tend to develop less defects within a service period of three to four years by average or shorter compared to what has been observed in various tanks on the LCF's. The current condition therefore does not meet the normal expectations.

The applied coating systems are intended to adequately protect the steel surface against corrosion for a period of 15-20 years. Based on the results of the surveys, it can be expected that the extent of the defects will increase in time.

The observed defects will result in a shortening of the service life of the coating systems. It is not possible to exactly quantify the remaining life time. Consequently, maintenance will have to be increased.

Design

- In tanks, it has been frequently observed that damages have occurred due to welding irregularities (incomplete, pinholes, etc.). This has resulted in corrosion in mainly potable water tanks and water ballast tanks.
- On LCF 1, various fuel tanks and the dirty oil tank have not been coated completely. Bare steel surfaces have developed (superficial) corrosion. On other LCF's, these tanks have been coated completely. Ensuring that fuel tanks remain free of defects for longer periods can possibly be achieved by applying higher coating thicknesses or selection of a different coating system.
- The water ballast tank coating system appears to be sensitive to cathodic protection, which results in blistering around weak spots covering far larger surfaces than the weak spots themselves.
- Corrosion is initiated alongside edges of deck coverings close to welding corners. These areas are difficult to maintain.
- Material selections (metals) appeared not to have been the most suitable everywhere.
- Deck edges and water outlets on higher parts of the topsides corrode, resulting in vertical staining traces.

Selected coating systems

Most of the applied systems are considered to be appropriate for the selected environment. However, due to extensive amounts of failures and weakening, the following areas should have been coated with a different coating system:

- Sewage tanks
- Grey water tanks (no. 2)
- Underwater hulls LCF 3 and 4; AlphaGen 20 antifouling
- Exterior topcoat (provided that observed fading is not acceptable)
- Deck covering on F-deck (prevention of impact ammunition)

Application of coating systems

Generally, application of the coating system varied between poor to reasonable.

- Water ballast tanks show very many to extreme amounts of corroded spots.
- In the potable water tanks, blistering has occurred between stripe coats and full coats on three LCF's.
- Substandard coating thickness and excessive thicknesses have been observed resulting in premature corrosion and cracking respectively.
- The Sigmaguard EHB system is prone to pinhole formation in corners.
- The quality of the application could have been better in heli fuel tanks; shortcomings though have not resulted in corrosion due to the absence of water.

The observed problems are an indication for a lacking quality control / quality assurance system of the coating contractor and also of the supervising party.

Maintenance

LCF's are exposed to harsh marine conditions (salt water, condens, UV) and exterior surfaces are also affected due to mechanical impact (topsides/F-deck ammunition/bilges). This can be considered as normal wear and tear. The long term consequences of these impacts can be reduced when maintenance is carried out. The impression was obtained though that maintenance has been minimal. For obvious reasons maintenance can only be realised when environmental legislation can be met and for areas which are directly accessible for the vessel's crew. Regular cleaning of surfaces could have resulted in a better optical impression. Application of repair coats on areas which develop corrosion can slow down the corrosion process.

4 Recommendations

Based on the extensive survey of four frigates and the defects which have been disclosed in the coating systems applied in various areas, a number of recommendations is given in order to decrease failures on future newbuildings. Inspections have shown that an increased quality control (QC) approach of the preservation process may indeed result in an improvement. A cost impact calculation for these improvements is not included in this study. A proper application and inspection regime during newbuilding will result in lower repair and maintenance costs, thus lowering the life cycle costs. The inspection activities during newbuilding can be carried out by yard, owner, paint manufacturer or an independent party. It is stipulated that inspection personnel is to be properly skilled and needs to have a mandate for corrective actions.

More data can be gathered when regular inspections during the service period are carried out. A standard format is to be used to facilitate the inspections and to ensure that results of different inspections, possible carried out by different persons, can be compared. Possibly, more sophisticated inspection tools can be employed to monitor the development of corrosion and breakdown of the coating system and which do not require entering of tanks. The execution of repairs is to be supervised and documented as well. An update of the inspection and maintenance strategy is beneficial.

General

- The inspections have revealed that the severe marine environment frigates are exposed to have resulted in wear and tear and affects the (visual) appearance of the frigates. Therefore, increased and more structural cleaning and maintenance operations by the crew could be considered during the service period as well.
- Finally, it could be considered to incorporate a clear guarantee agreement between involved parties on the allowed condition after various years of service, including a description of the types and amounts of defects. Evaluation of the condition can be realized by a joint inspection of involved parties or an independent third part, provided that conclusions of a third party will be accepted on beforehand.
- Clearer specifications and more stringent control of the steel belt joint condition prior to coating resulting in smoother surfaces (especially for tanks).

Tanks

- More stringent control, inspection and remedial actions to improve the welding quality in tanks to ensure application of complete welds, reduce pinholes and uneven areas.
- A review of coating specifications which should result in fewer failures. Examples are the sewage tanks which have been affected by blistering and grey water tank 2. It is preferred to select a phenolic epoxy coating system in these aggressive environments. Selection of a ballast tank coating system (pretreatment in combination with coating system) which is less prone to cathodic blistering.
- Execution of high voltage porosity tests and salt water tests for the heavy duty tank coating systems to disclose weak spots in the coating systems prior to delivery.
- Improvement of the spraying techniques to reduce saggings and pinhole formation. When needed, stripe coating is to be executed before application of a full coat.

Bilges

- Pitting corrosion has occurred in bilges of especially pump rooms 2 and 3. Mechanical damages have most likely created a direct access to the steel substrate for sulphur reducing bacteria (SRB's, positively identified in pump room 2 on LCF 1). The occurrence of mechanical damages can not be prevented and is considered to be normal wear and tear in bilges.
- Regular cleaning to remove sludge and oil from bilges and/or mounting of sacrificial anodes resulting in a reduced risk of bacterial corrosion.

Decks

- Adjustment of the specification for the decks. The anti slip material should not be applied until welding corners but only until a distance of approx. 10 cm. This will facilitate maintenance. Alternatively, the thick deck covering system, without anti-slip top layer, can be applied across the first 5-10 cm of vertical areas. This will also ensure additional protection of welding corners provided that the coating system is not susceptible to stress cracking (use solvent free system).
- Regular cleaning of decks to reduce dirt retention.
- The areas around the canon on deck F (forward) have been damaged by falling ammunition. Usage of rubber sheets on LCF 3 has prevented the mechanical impact. Alternatively a more elastic, shock absorbing system could be selected here.

Topsides/superstructure

- The selected coating system shows a significant gloss reduction and starts powdering within two years of service. It needs to be considered if this is an acceptable rate of breakdown.
- Additional protective measures for specific areas which are subject to major mechanical impact (coamings around crane decks, edges heli deck).
- Crew maintenance can be considered to slow down the aging of the coating systems. Care is to be taken that proper maintenance procedures can (environmental issue and legislation) and will be (meeting technical recommendations) followed.
- Review of specifications for equipment which is delivered completely (including full commercial coating system) and mounted on board (selection of metals, galvanic coupling, edge coverage, etc.).

It is expected that follow up of these recommendations will finally result in better performances and reduced maintenance costs of the various coating systems.

5 Signature

Eindhoven, March 2008

TNO Science and Industry

G.M. Ferrari, M.Sc.
Program Leader

TNO Quality Services B.V.

R. van der Kaaden, B.Sc.
Project Leader

Appendix 1: Photos

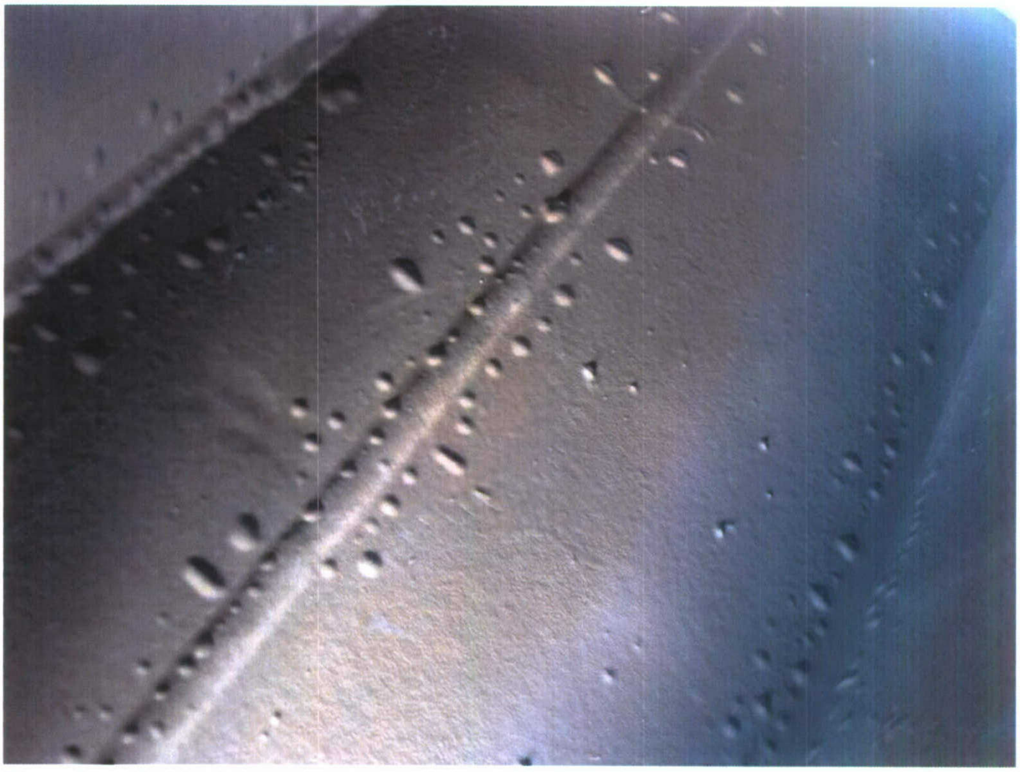


Photo 1: Hr.Ms. "Zeven Provinciën" (LCF 1). Potable water tank 2 (07.11.2006).
Blistering along welds/welding corners in stripe coated areas.

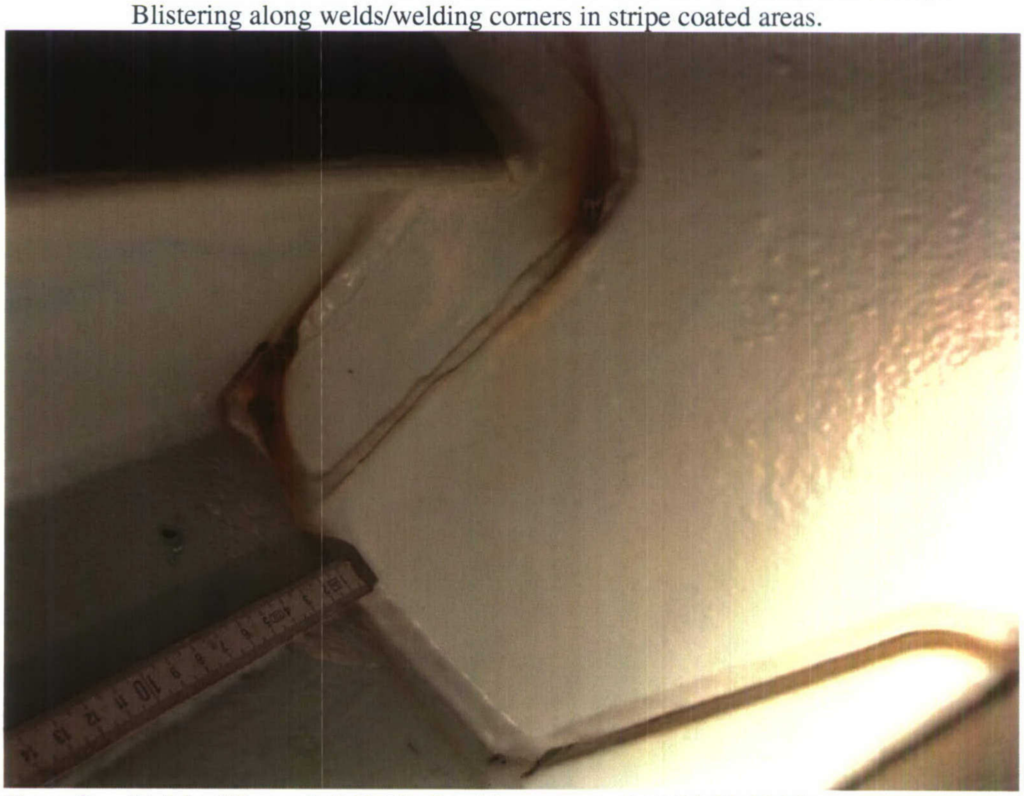


Photo 2: Hr.Ms. "Tromp" (LCF 2). Potable water tank 4 (02.08.2006).
Corroded spots along welds.

Appendix 1: Photos (continuation)

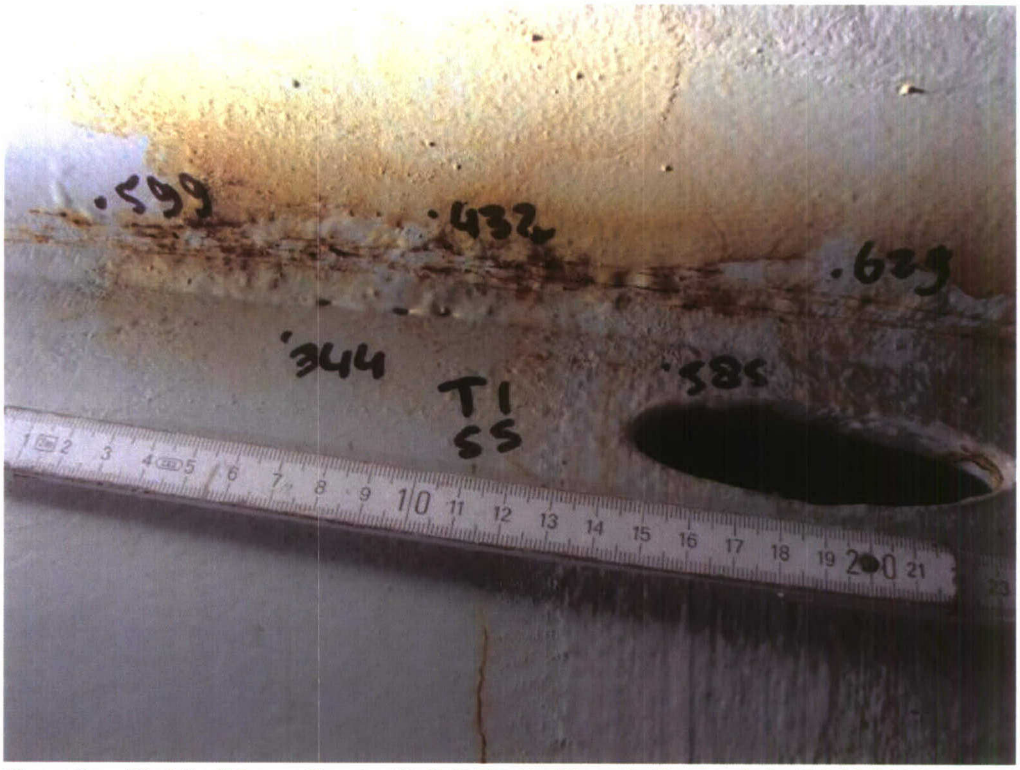


Photo 3: Hr.Ms. "Zeven Provinciën" (LCF 1). Water ballast tank 2. (06.09.2006).
Cracks in coating along deckhead weld.

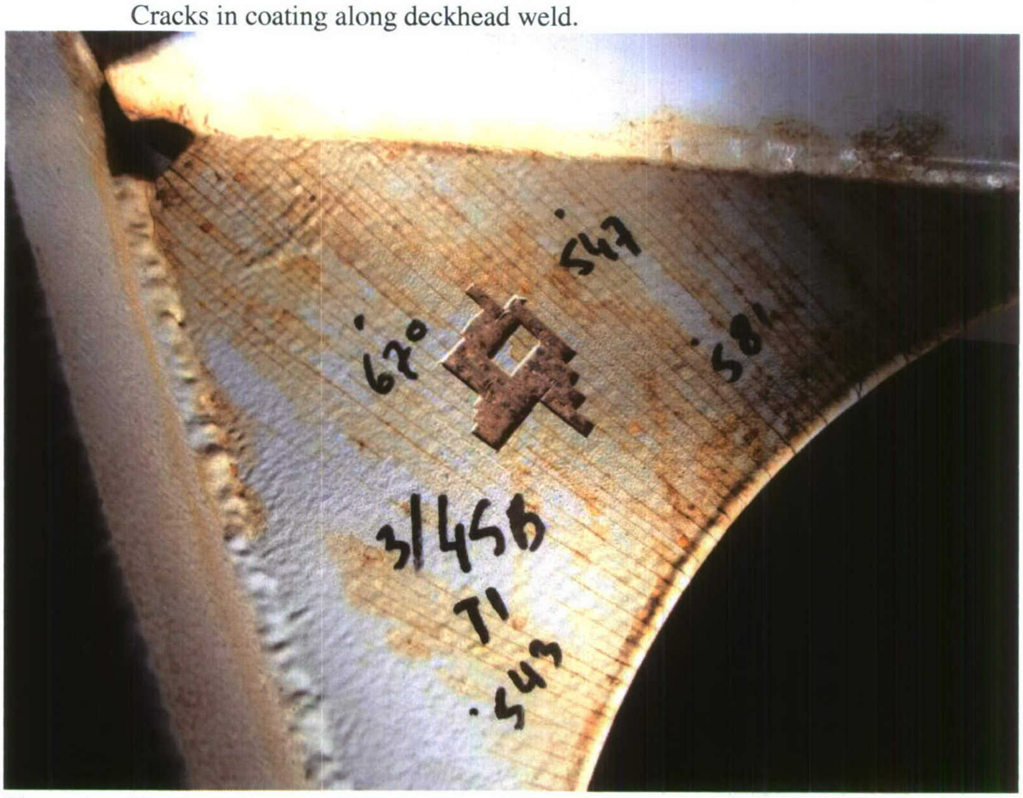


Photo 4: Hr.Ms. "Tromp" (LCF 2). Water ballast tank 1. (11.08.2006).
Cracks in coating on bracket. Limited undercreep of corrosion from cracks.

Appendix 1: Photos (continuation)

Photo 5: Hr.Ms. "Evertsen" (LCF4). Water ballast tank 1 (04.04.2006).
Large numbers of mechanical damages with protruding corrosion and staining.

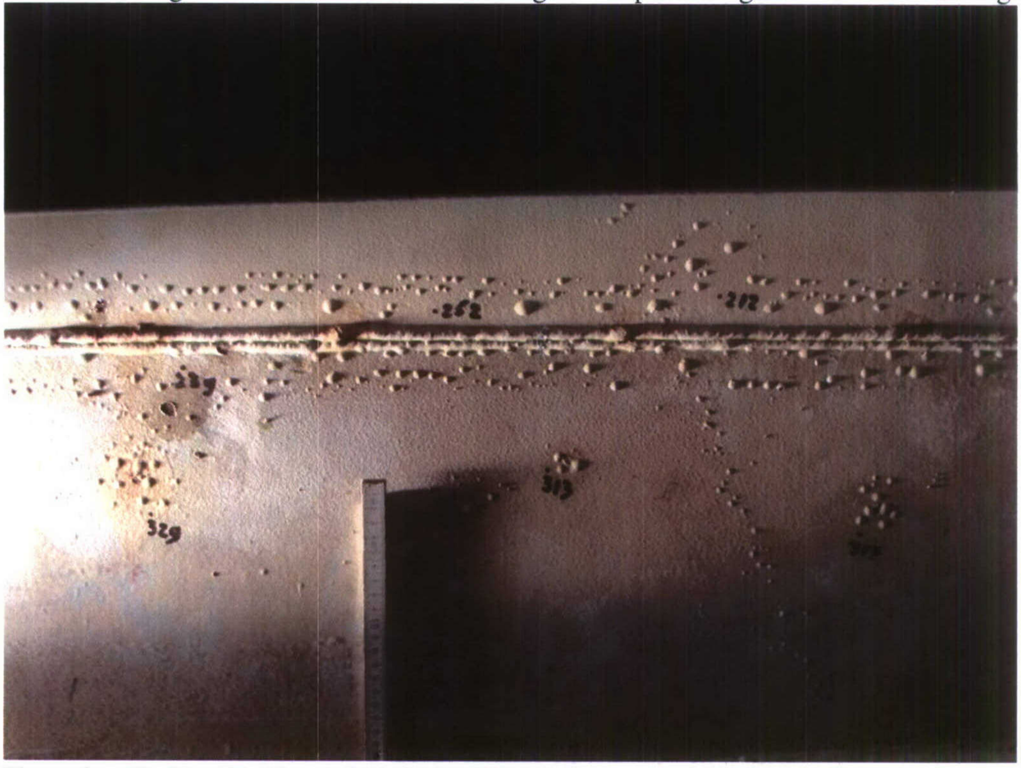


Photo 6: Hr.Ms. "De Ruyter" (LCF 3). Water ballast tank 5 (08.11.2006).
Poorly covered weld with substandard coating thickness and cathodic blistering.

Appendix 1: Photos (continuation)

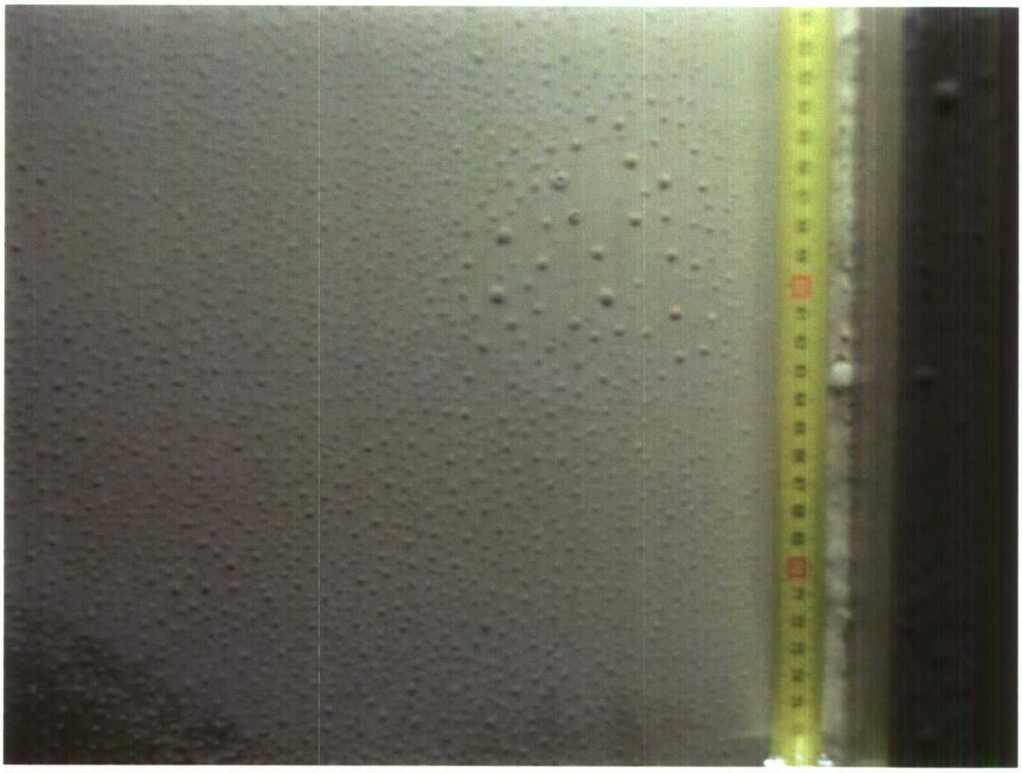


Photo 7: Hr.Ms. "Tromp" (LCF 2). Sewage collection tank (11.07.2006).
Severe blistering on bulkhead.

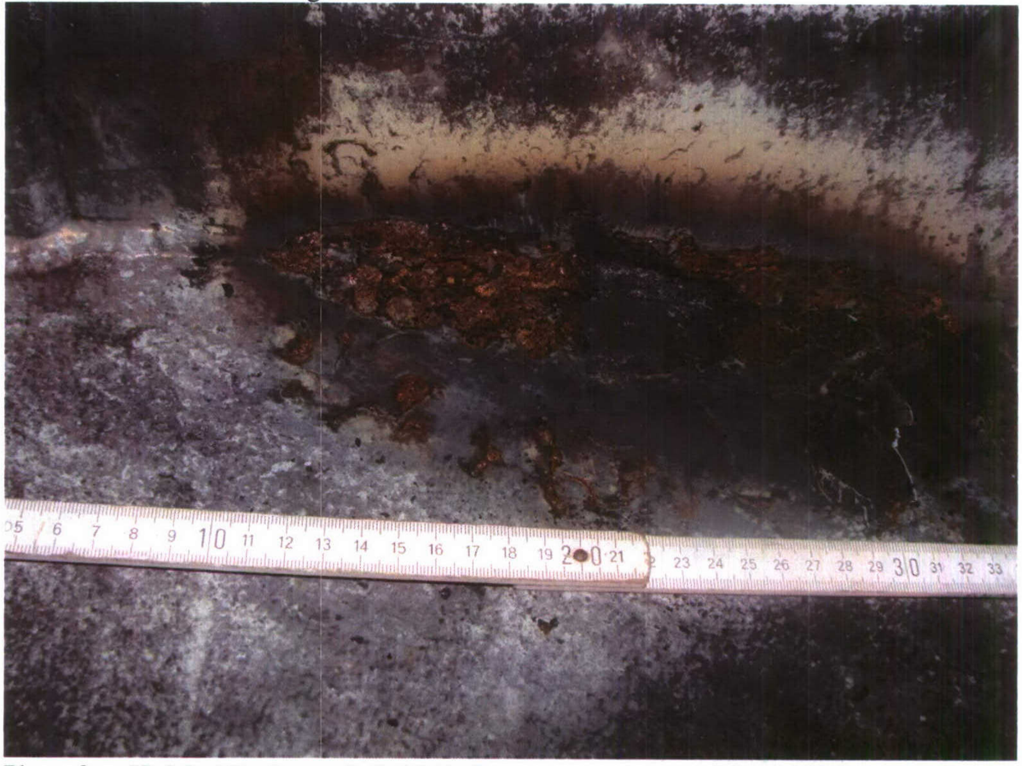


Photo 8: Hr.Ms. "De Ruyter" (LCF 3). Sewage storage tank (13.11.2006).
Corrosion on tank bottom.

Appendix 1: Photos (continuation)

Photo 9: Hr.Ms. "Zeven Provinciën" (LCF 1). Sewage storage tank 3 (11.09.2006). Severe wastage of Cunifer piping in SB compartment and under sewage collection tank.

Photo 10: Hr.Ms. "Zeven Provinciën" (LCF 1). Fuel storage tank 3 (26.06.2006). Areas which have not been primed have developed corrosion.

Appendix 1: Photos (continuation)

Photo 11: Hr.Ms. "De Ruyter" (LCF 3). Fuel consumption tank KVD/DG SB (14.11.2006). Corrosion on hull plating in corner towards deckhead.

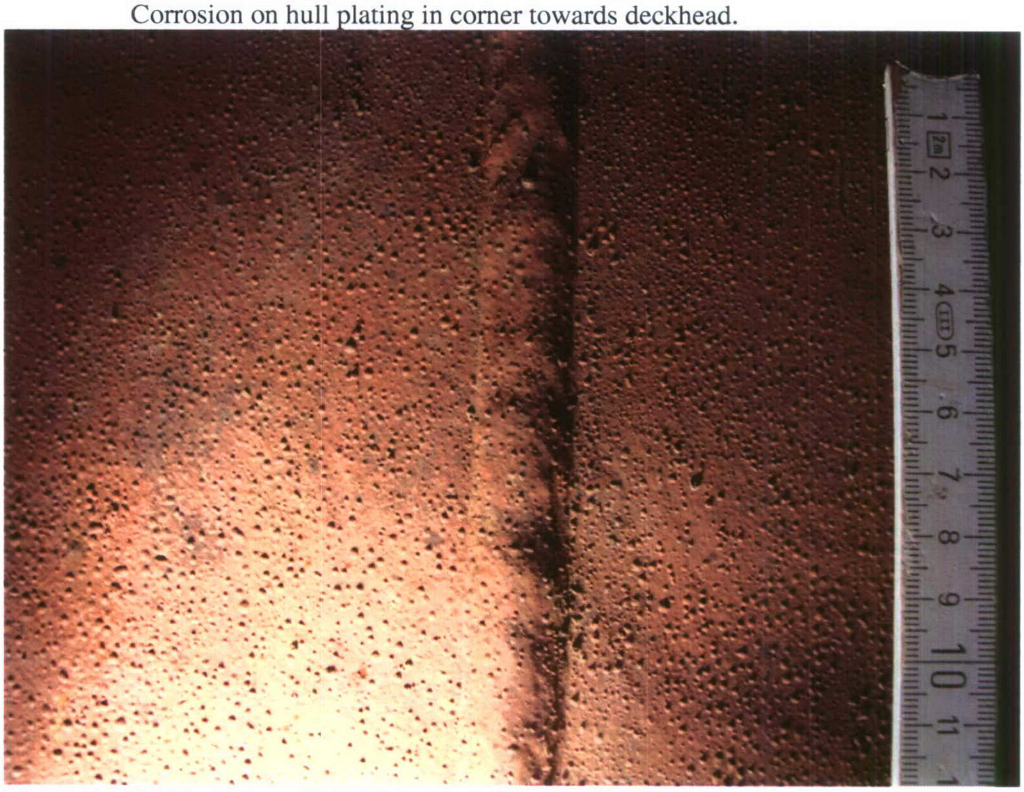


Photo 12: Hr.Ms. "Tromp" (LCF 2). Fuel storage tank 1 (03.08.2006). Dense blistering on tank bottom.

Appendix 1: Photos (continuation)

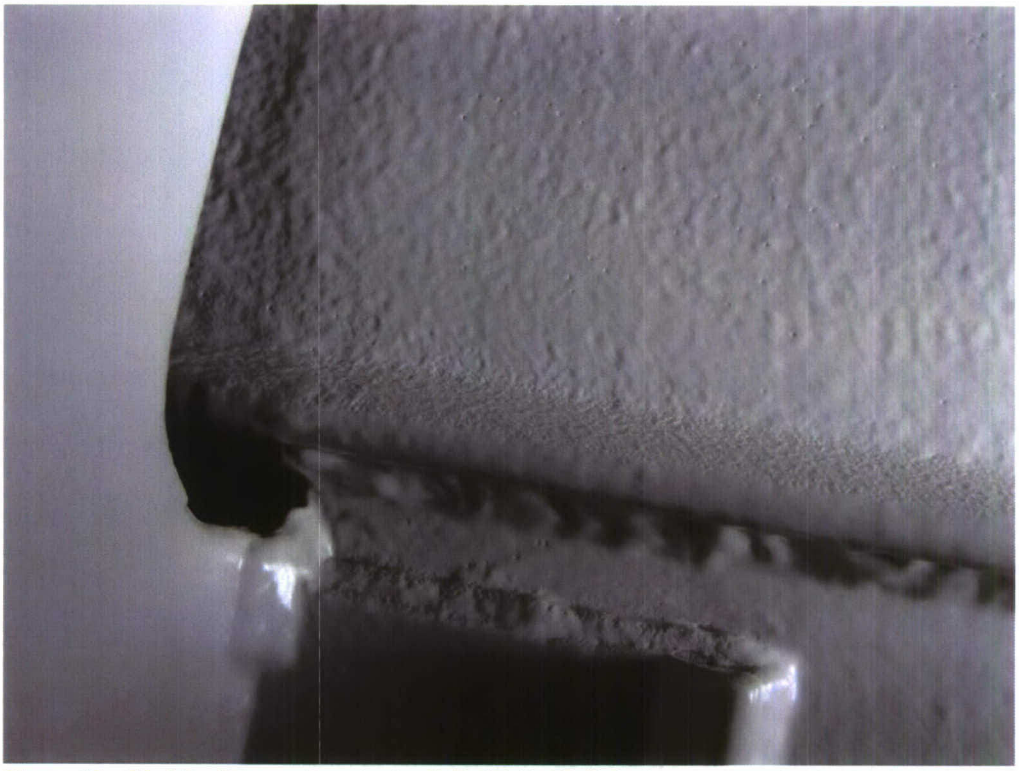


Photo 13: Hr.Ms. "Zeven Provinciën" (LCF 1). Heli fuel storage tank (21.08.2007).
Poorly covered edges and pinhole formation in topcoat.

Photo 14: Hr.Ms. "Zeven Provinciën" (LCF 1). Grey water tank 2 (26.06.2007).
Severe breakdown on forward and starboard bulkhead.

Appendix 1: Photos (continuation)

Photo 15: Hr.Ms. "Evertsen" (LCF4). Bilge water collection tank (14.03.2006).
Corrosion along poorly covered weld in centre compartment.

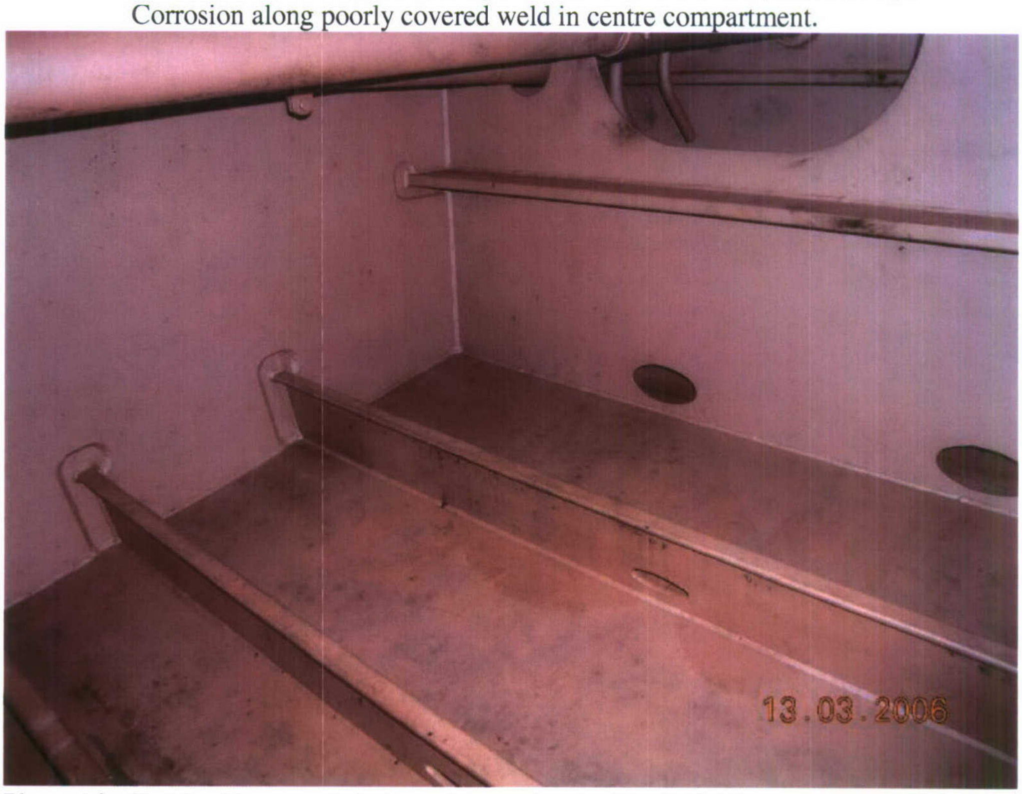


Photo 16: Hr.Ms. "Evertsen" (LCF4). Dirty oil tank (13.03.2006).
Overview of a part of the centre compartment.

Appendix 1: Photos (continuation)

Photo 17: Hr.Ms. "Zeven Provinciën" (LCF 1). Dieselgeneratorroom (25.06.2007).
Dirty, oily bottom area with staining due to corrosion of metal particles on top of coating.

Photo 18: Hr.Ms. "De Ruyter" (LCF 3). Pump room 3 (14.11.2006).
Pitting corrosion on hull and vertical side in compartment 3 from fore.

Appendix 1: Photos (continuation)

Photo 19: Hr.Ms. "Tromp" (LCF 2). Underwater hull (28.06.2006).
The SB forward surface area is in excellent condition.

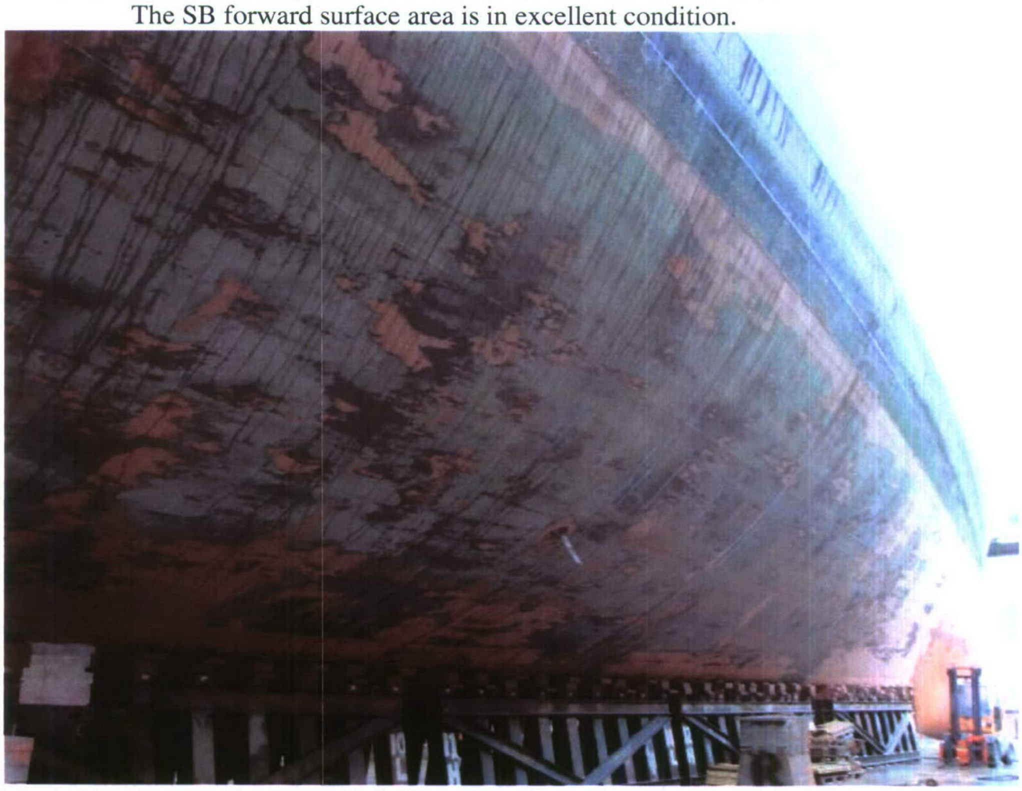


Photo 20: Hr.Ms. "De Ruyter" (LCF 3). Underwater hull (07.12.2006).
Significant detachment of antifouling on SB forward area.

Appendix 1: Photos (continuation)

Photo 21: Hr.Ms. "De Ruyter" (LCF 3). Topside (07.12.2006).
Corrosion along edges and staining of corrosion products on SB aft area.

Photo 22: Hr.Ms. "De Ruyter" (LCF 3). Topside (07.12.2006).
Corroded spots and detachment of touch up layer on SB during cleaning.

Appendix 1: Photos (continuation)

Photo 23: Hr.Ms. "Zeven Provinciën" (LCF 1). Topside (22.08.2007).
Detachment above boottop and along horizontal weld on PS forward area.

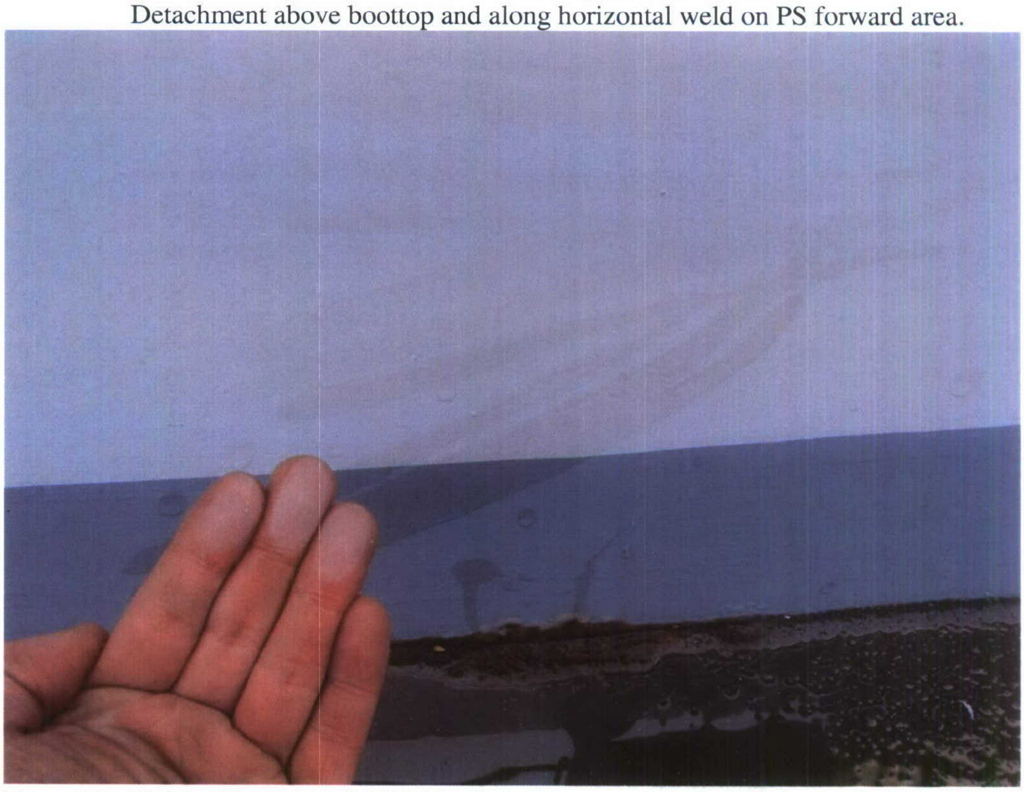


Photo 24: Hr.Ms. "De Ruyter" (LCF 3). Superstructure (08.12.2006).
C deck. Powdery coating surface. Corrosion along welding corner.

Appendix 1: Photos (continuation)

Photo 25: Hr.Ms. "De Ruyter" (LCF 3). Superstructure (08.12.2006).
D deck. SB forward. Corrosion around stainless steel head screws.

Photo 26: Hr.Ms. "Evertsen" (LCF4). Superstructure (14.03.2006).
D deck. PS forward. Corrosion on various details.

Appendix 1: Photos (continuation)

Photo 27: Hr.Ms. "Zeven Provinciën" (LCF 1). Deck (25.06.2007).
F deck. PS forward. Corroded spots and cracks in deck covering.

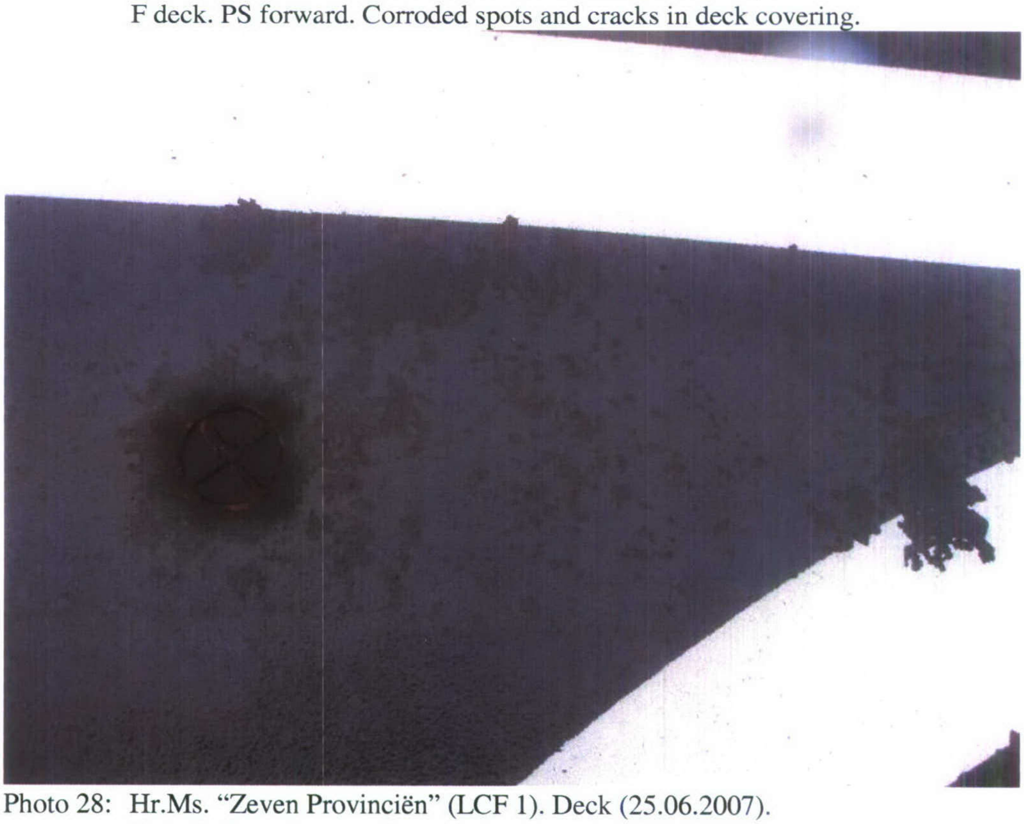


Photo 28: Hr.Ms. "Zeven Provinciën" (LCF 1). Deck (25.06.2007).
G deck. Detachment of topcoat and corrosion of lashing point.

Appendix 1: Photos (continuation)

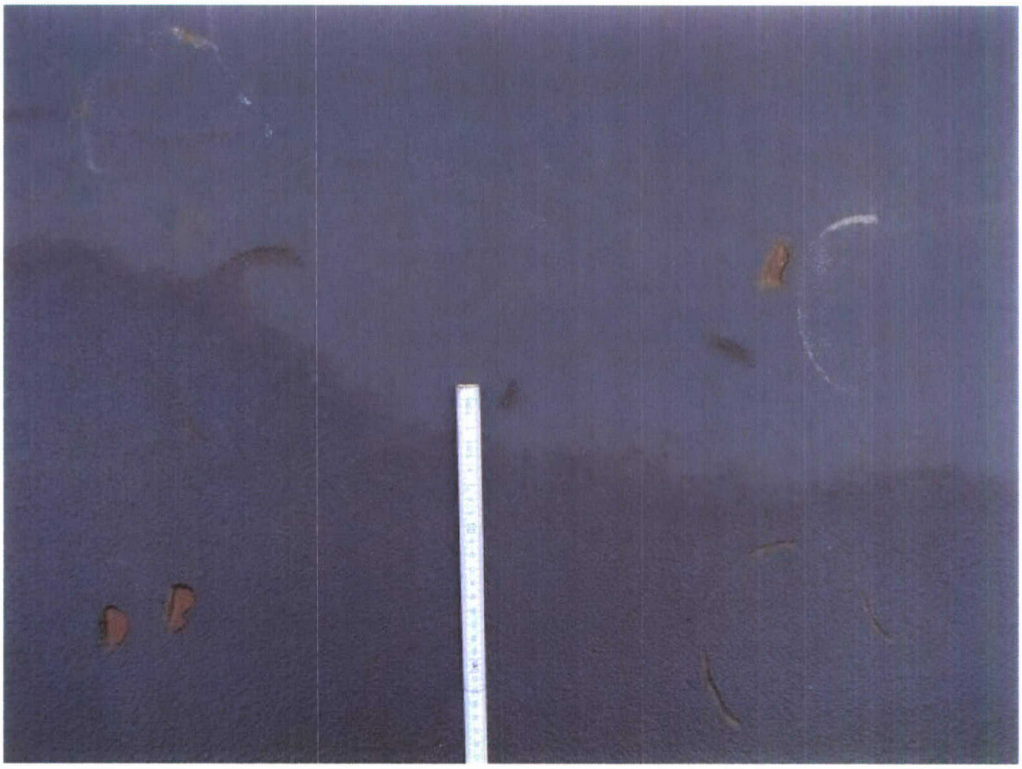


Photo 29: Hr.Ms. "Tromp" (LCF 2). Deck (04.08.2006).
F deck. PS forward. Damages caused by falling ammunition.

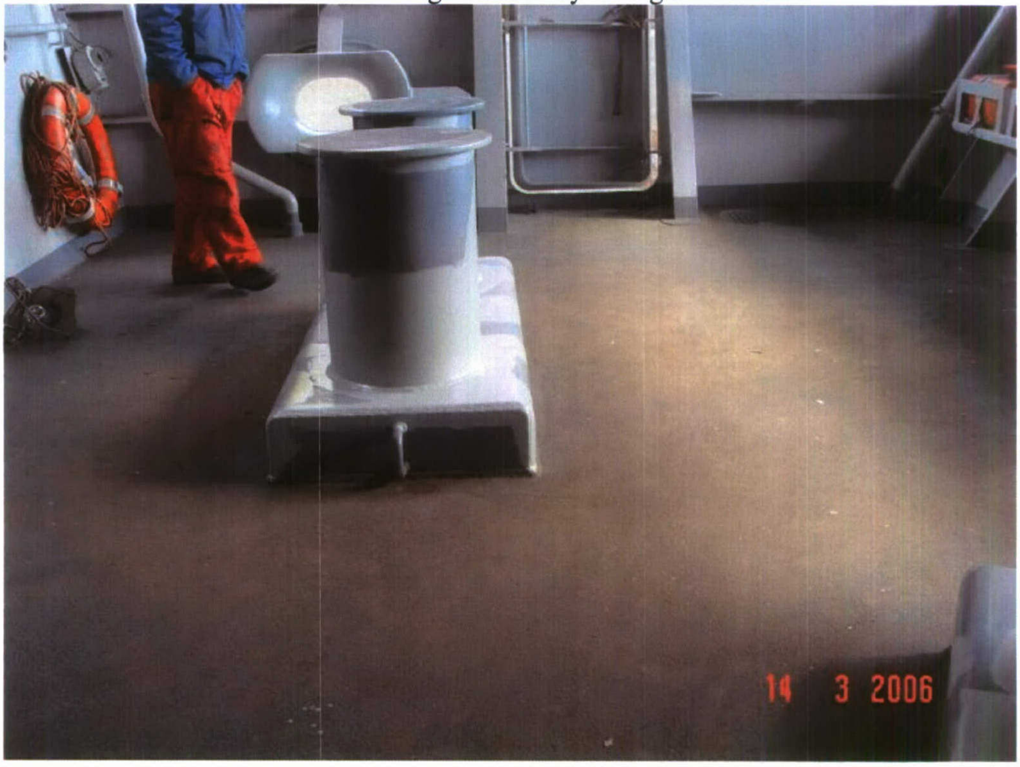


Photo 30: Hr.Ms. "Evertsen" (LCF4). Deck (14.03.2006).
H deck. Dirty surface.

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10. TITLE AND SUBTITLE

Summary of coating surveys on the four air command frigates (Zeven Provinciën class)

11. AUTHOR

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14. SUPPLEMENTARY NOTES

The classification designation Ongerubriceerd is equivalent to Unclassified.

15. ABSTRACT (MAXIMUM 200 WORDS (1044 BYTE))

The condition of coating systems on board of four air command frigates (Zeven Provinciën class) is subject to discussions within the Royal Netherlands Navy. An inventory has been made into the current condition of coating systems applied in a selection of various tanks and bilges, underwater hulls, topsides/superstructure and deck coverings. Types of defects and surface areas affected by these defects have been assessed accurately. Causes have been investigated. The survey has revealed that some of the selected coating systems are not fit for purpose (sewage tanks, grey water tank 2, antifouling on LCF 3/4, deck covering F deck). The quality of the steel works (welding) can be improved, the application of the coating systems varied between poor to reasonable and several material selections/combinations on the superstructure were unfavourable. Bilges in pump rooms 2 and 3 are sensitive to pitting corrosion. These shortcomings and the lack of maintenance have resulted in a performance which is poorer than expected considering the short service period for various parts. Better results can be attained following a review of coating specifications, when quality control during newbuilding is improved and more cleared guarantee agreements are drafted.

16. DESCRIPTORS			IDENTIFIERS
coating systems	durability	maintenance	
coating failures	specifications		

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